§14. Effects of the Net Plasma Current on the Onset of the Sawtooth Crash and Period

Takagi, S. (Dep. Energy Eng. Science, Nagoya Univ.), Toi, K., CHS Group

A tokamak plasma configuration with negative magnetic shear ($q' < 0$) attracts much interest as an operational mode which enables to attain high beta and high confinement plasmas with large bootstrap current fraction in a future economical steady-state reactor. In recent negative magnetic shear experiments in several tokamaks, $q = 2$ off-axis sawteeth which lead to plasma collapse only in an annular region around the $q = 2$ surface are often observed. In CHS, where the rotational transform profile is similar to that in the nagative magnetic shear configuration of a tokamak, $q = 2$ off-axis sawtooth oscillations are often observed in NBI heated plasmas. Comparison study of this type of sawtooth in CHS with that in the negative magnetic shear tokamak is important and interesting. The investigation of another type of sawtooth crash other than a familiar $q = 1$ sawtooth crash may give us much information about magnetic reconnection physics in a toroidal plasma.

Although magnetic configuration is basically formed only by external coils without large toroidal net current, tangentially injected neutral beams can drive the toroidal net current in the co-direction. The beam-driven current by the co-injected NBI is sufficiently small to destabilize current-driven instabilities, but can appreciably modify the rotational transform profile. Pressure-driven instabilities become unstable, because magnetic shear and magnetic well region are decreased by this co-flowing current. Thus, the effects of the net current are important for stabilization of pressure-driven MHD instabilities. In CHS, sawtooth oscillations are observed in relatively low density ($\bar{n}_e \simeq 1 - 3 \times 10^{19}\,\mathrm{m}^{-3}$) and low beta (plasma beta evaluated from diamagnetic measurement $\langle\beta_{dia}\rangle \leq 0.5\,\%$) plasmas with a small net plasma current ($I_p \simeq 5 - 15\,\mathrm{kA}$), which is induced by co-injected NBI. In Fig. 1, data points of I_p and $\langle\beta_{dia}\rangle$ are plotted for the conditions with and without sawtooth crashes, at $B_\phi = 1.2$ and 1.5 T. Lower current limit for the appearance of sawtooth crashes (for example, $I_p \sim 7\,\mathrm{kA}$ at $B_\phi = 1.2\,\mathrm{T}$) tends to decrease with the decrease in B_ϕ. In these cases, the rotational transform profile including net current effects is similar for respective lower bound of the plasma current at $B_\phi = 1.2$ and 1.5 T. This indicates the existence of threshold value of magnetic shear that may cause the sawtooth crash.

For the sawtooth period τ_{saw} (repetition time of the sawtooth crash), much attention is paid from a viewpoint of the MHD stability. In CHS, the sawtooth period sensitively depends on the value of the net plasma current (i.e. reduction of the magnetic shear near the $q = 2$ surface and the magnetic well region). The sawtooth periods τ_{saw} in the case of $B_\phi = 1.5\,\mathrm{T}$ are shown in Fig. 2. The period τ_{saw} tends to decrease with the increase in the net plasma current.

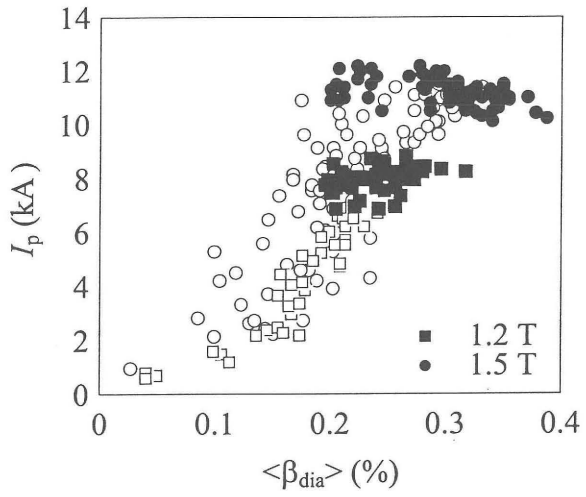

Figure 1: Plasma conditions where sawtooth crashes are observed are summaraized on I_p - $\langle\beta_{dia}\rangle$ plane. Solid symbols indicate the conditions with sawtooth crashes, and open ones for no sawtooth crash.

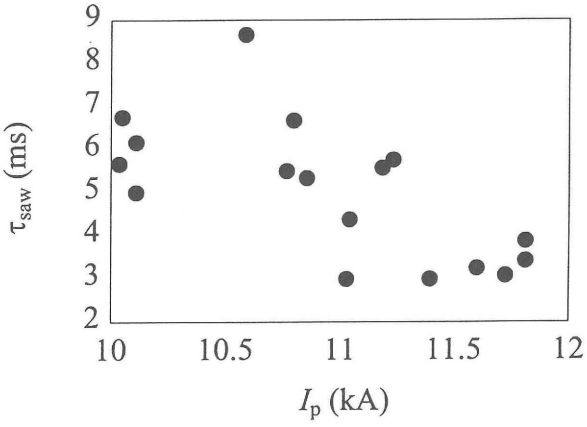

Figure 2: Sawtooth period as a function of the net plasma current in the case of $B_\phi = 1.5\,\mathrm{T}$